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Lewis Research Center

Study of Hot Hardness Characteristics of Tool Steels

Short-term hot hardness studies (the hardness property of a material after tempering as related to its room temperature hardness level) were performed with five vacuum-melted steels: AISI 52100, AISI M-1, AISI M-50, Halmo, and WB-49. An equation was developed to predict the short-term hardness at a given temperature as a function of the initial room temperature hardness.

Previous studies performed to compare the hot hardness properties of various materials have not compared the hot hardness properties of the same materials after tempering to various room temperature hardness levels, nor have they compared different materials tempered to the same room temperature hardness.

Tool steels have been used with increasing frequency as a rolling-element bearing material, and in these applications the minimum hardness required is Rockwell C 58 at operating temperature.

Hardness measurements on each material tested were taken at elevated temperatures in an electric furnace with a low oxygen environment. This ensured that decarburization and oxidation would not affect the results. Test temperatures range from 294 to 887 K (70 to 1140°F). Test data showed that, regardless of the initial hardness, the hot hardness of the individual materials has the same functional dependence. The data also indicated that the change in hardness of the high-speed tool steels was independent of material composition. Therefore, based upon a minimum Rockwell C hardness of 58 at operating temperature, the limiting temperature in using these materials is dependent upon tempering temperatures and the initial room temperature hardness of the material.

An equation was developed to predict the short-term hardness as a function of initial room temperature hardness of both AISI 52100 and high-speed tool steel. These materials are precipitation-hardening alloys. As the temperature of the material is raised, it begins to over-age and soften. When the operating temperature nears the tempering temperature, this process is accelerated and the hardness is decreased more rapidly. As the test temperature is raised beyond the tempering temperature, the precipitation-hardening precipitate particles increase in size and decrease in number, and the material begins to spheroidize. At this point, the greatest decrease in hardness occurs, and the hardness of the material tends to decrease toward the fully annealed condition.

Test results verified that the following equation can predict the short-term Rockwell C hardness at a given temperature to within ± 1 point Rockwell C:

$$(Rc)_T = (Rc)_{RT} - \alpha \Delta T^{\beta}$$

where:

- $(Rc)_T$ = Rockwell C hardness at operating temperature;
- $(Rc)_{RT}$ = Rockwell C hardness at room temperature;
- ΔT = change in temperature, $T_T - T_{RT}$;
- T_T = operating temperature in Kelvin (K) or Farenheit (F) degrees;
- T_{RT} = room temperature; in Kelvin (K) or Farenheit (F) degrees;
- α = temperature proportionality factor, whose value depends on the degree scale, Kelvin or Farenheit; and
- β = exponent.

This equation is applicable to approximately 20 high-speed tool steels with the same degree of accuracy.

Notes:

1. This easily adapted equation should be of interest to manufacturers of bearings, drills, tools, dies, cutters, gears, reamers, taps and saws.

(continued overleaf)

2. The following documentation may be obtained from:
National Technical Information Service
Springfield, Virginia 22151
Single document price $3.00
(or microfiche $0.95)

Reference: NASA TN-D-6632 (N72-15461), Short-Term Hot Hardness Characteristics of Rolling-Element Steels

3. Technical questions may be directed to:
Technology Utilization Officer
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Cleveland, Ohio 44135
Reference: B72-10583

Patent status:

NASA has decided not to apply for a patent.

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